Transverse-Momentum and Pseudorapidity Distributions of Charged Hadrons in pp Collisions at $\sqrt{s} = 7$ TeV

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(Received 18 May 2010; published 6 July 2010)

Charged-hadron transverse-momentum and pseudorapidity distributions in proton-proton collisions at $\sqrt{s} = 7$ TeV are measured with the inner tracking system of the CMS detector at the LHC. The charged-hadron yield is obtained by counting the number of reconstructed hits, hit pairs, and fully reconstructed charged-particle tracks. The combination of the three methods gives a charged-particle multiplicity per unit of pseudorapidity $dN_{\mathrm{ch}}/d\eta|_{|\eta|<0.5} = 5.78 \pm 0.01(\mathrm{stat}) \pm 0.23(\mathrm{syst})$ for non-single-diffractive events, higher than predicted by commonly used models. The relative increase in charged-particle multiplicity from $\sqrt{s} = 0.9$ to 7 TeV is $[66.1 \pm 1.0(\mathrm{stat}) \pm 4.2(\mathrm{syst})]\%$. The mean transverse momentum is measured to be $0.545 \pm 0.005(\mathrm{stat}) \pm 0.015(\mathrm{syst})$ GeV$/c$. The results are compared with similar measurements at lower energies.

DOI: 10.1103/PhysRevLett.105.022002 PACS numbers: 13.85.Ni

Introduction.—Measurements of particle yields and kinematic distributions are an essential first step in exploring a new energy regime of particle collisions. Such studies contribute to our understanding of the physics of hadron production, including the relative roles of soft and hard scattering contributions, and help construct a solid foundation for other investigations. In the complicated environment of LHC pp collisions [1], firm knowledge of the rates and distributions of inclusive particle production is needed to distinguish rare signal events from the much larger backgrounds of soft hadronic interactions. They will also serve as points of reference for the measurement of nuclear-medium effects in Pb-Pb collisions in the LHC heavy ion program.

The bulk of the particles produced in pp collisions arise from soft interactions, which are modeled only phenomenologically. Experimental results provide the critical guidance for tuning these widely used models and event generators. Soft collisions are commonly classified as elastic scattering, inelastic single-diffractive (SD) dissociation, double-diffractive (DD) dissociation, and inelastic nondiffractive (ND) scattering [2]. (Double-Pomeron exchange is treated as DD in this Letter.) All results presented here refer to inelastic non-single-diffractive (NSD) interactions, and are based on an event selection that retains a large fraction of the ND and DD events, while disfavoring SD events.

The measurements focus on transverse-momentum p_T and pseudorapidity η distributions. The pseudorapidity, commonly used to characterize the direction of particle emission, is defined as $\eta = -\ln \tan(\theta/2)$, where θ is the polar angle of the direction of the particle with respect to the anticlockwise beam direction. The count of primary charged hadrons N_{ch} is defined to include decay products of particles with proper lifetimes less than 1 cm. Products of secondary interactions are excluded, and a percent-level correction is applied for prompt leptons. The measurements reported here are of $dN_{\mathrm{ch}}/d\eta$ and dN_{ch}/dp_T in the pseudorapidity range $|\eta| < 2.4$ and closely follow our previous analysis of minimum-bias data at lower center-of-mass energies of $\sqrt{s} = 0.9$ and 2.36 TeV as reported in Ref. [3].

The data for this study are drawn from an integrated luminosity of 1.1 μb^{-1} recorded with the Compact Muon Solenoid (CMS) experiment [4] on 30 March 2010, during the first hour of the LHC operation at $\sqrt{s} = 7$ TeV. These results are the highest center-of-mass energy measurements of the $dN_{\mathrm{ch}}/d\eta$ and dN_{ch}/dp_T distributions conducted at a particle collider so far and complement the other recent measurements of the ALICE experiment at 7 TeV [5].

Experimental methods.—A detailed description of the CMS experiment can be found in Ref. [4]. The detectors used for the present analysis are the pixel and silicon-strip tracker, covering the region $|\eta| < 2.5$ and immersed in a 3.8 T axial magnetic field. The pixel tracker consists of three barrel layers and two end-cap disks at each barrel end. The forward calorimeter (HF), which covers the region $2.9 < |\eta| < 5.2$, was also used for event selection. The detailed Monte Carlo (MC) simulation of the CMS detector response is based on GEANT4 [6].

The event selection and analysis methods in this Letter are identical to those used in Ref. [3], where more details can be found. The inelastic pp collision rate was about 50 Hz. At these rates, the fraction of events in the data,

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TABLE I. Numbers of events passing the selection cuts. The selection criteria are applied in sequence, i.e., each line includes the selection from the previous ones.

Selection	Number of events
Colliding bunches + one BSC signal	68 512
Reconstructed PV	61 551
HF coincidence	55 113
Beam-halo rejection	55 104
Other beam-background rejection	55 100

where two or more minimum-bias collisions occurred in the same bunch crossing, is estimated to be less than 0.3% and was neglected. Any hit in the beam scintillator counters (BSC, $3.23 < |\eta| < 4.65$) coinciding with colliding proton bunches was used for triggering the data acquisition. A sample mostly populated with NSD events was selected by requiring a primary vertex (PV) to be reconstructed with the tracker, together with at least one HF tower in each end with more than 3 GeV total energy. Beam-halo and other beam-background events were rejected as described in Ref. [3]. The remaining fraction of background events in the data was found to be less than 2×10^{-5}. The numbers of events satisfying the selection criteria are listed in Table I.

The event selection efficiency was estimated with simulated events using the PYTHIA [7,8] and PHOJET [9,10] event generators. The relative event fractions of SD, DD, and ND processes and their respective event selection efficiencies are listed in Table II. The fraction of diffractive events is predicted by the models to decrease as a function of collision energy, while the selection efficiency increases. At $\sqrt{s} = 7$ TeV, the fraction of SD (DD) events in the selected data sample, estimated with PYTHIA and PHOJET, are 6.8% (5.8%) and 5.0% (3.8%), respectively, somewhat higher than at $\sqrt{s} = 0.9$ and 2.36 TeV [3]. With PYTHIA, the overall correction for the selection efficiency of NSD processes and for the fraction of SD events remaining in the data sample lowers the measured charged-particle multiplicity by 6% compared with the uncorrected distribution.

The $dN_{\mathrm{ch}}/d\eta$ distributions were obtained, as in Ref. [3], with three methods, based on counting the following quantities: (i) reconstructed clusters in the barrel part of the pixel detector; (ii) pixel tracklets composed of pairs of clusters in different pixel barrel layers; and (iii) tracks reconstructed in the full tracker volume. The third method also allows a measurement of the dN_{ch}/dp_T distribution. All three methods rely on the reconstruction of a PV [11]. The PV reconstruction efficiency was found to be 98.3% (98.0%) in data (MC), evaluated after all other event selection cuts. In case of multiple PV candidates, the vertex with the largest track multiplicity was chosen. The three methods are sensitive to the measurement of particles down to p_T values of about 30, 50, and 100 MeV/c, respectively. Only 0.5, 1.5, and 5% of all charged particles are estimated to be produced below these p_T values, respectively, and these fractions were corrected for.

The measurements were corrected for the geometrical acceptance ($\approx$2%), efficiency ($\approx$5%–10%), fake (<1%) and duplicate tracks (<0.5%), low-p_T particles curling in the axial magnetic field (<1%), decay products of long-lived hadrons (<2%) and photon conversions (<1%), and inelastic hadronic interactions in the detector material ($\approx$1%–2%), where the size of the corrections in parentheses refers to the tracking method. The PYTHIA parameter set from Ref. [8] was chosen to determine the corrections, because it reproduces the $dN_{\mathrm{ch}}/d\eta$ and charged-particle multiplicity distributions, as well as other control distributions at 7 TeV, better than other available tuning parameter sets. Although the corrections do not depend significantly on the model used, it is indeed important that the simulated data set contains a sufficient number of high-multiplicity events to determine these corrections with the desired accuracy.

Results.—For the measurement of the dN_{ch}/dp_T distribution, charged-particle tracks with p_T in excess of 0.1 GeV/c were used in 12 different $|\eta|$ bins, from 0 to 2.4. The average charged-hadron yields in NSD events are shown in Fig. 1 as a function of p_T and $|\eta|$. The Tsallis parametrization [12–14],

$$E\frac{d^3N_{\mathrm{ch}}}{dp^3} = \frac{1}{2\pi p_T}\frac{E}{p}\frac{d^2N_{\mathrm{ch}}}{d\eta\, dp_T} = C\frac{dN_{\mathrm{ch}}}{dy}\left(1 + \frac{E_T}{nT}\right)^{-n}, \quad (1)$$

where $y = 0.5\ln[(E + p_z)/(E - p_z)]$, $E_T = \sqrt{m^2 + p_T^2} - m$, and m is the charged pion mass, was fitted to the data. The p_T spectrum of charged hadrons, $1/(2\pi p_T)d^2N_{\mathrm{ch}}/d\eta\, dp_T$, measured in the range $|\eta| < 2.4$, is shown in Fig. 2 for data

TABLE II. Fractions of SD, DD, ND, and NSD processes obtained from the PYTHIA and PHOJET event generators before any selection, and the corresponding selection efficiencies determined from the MC simulation.

	PYTHIA		PHOJET	
	Fractions	Selection efficiencies	Fractions	Selection efficiencies
SD	19.2%	26.7%	13.8%	30.7%
DD	12.9%	33.6%	6.6%	48.3%
ND	67.9%	96.4%	79.6%	97.1%
NSD	80.8%	86.3%	86.2%	93.4%

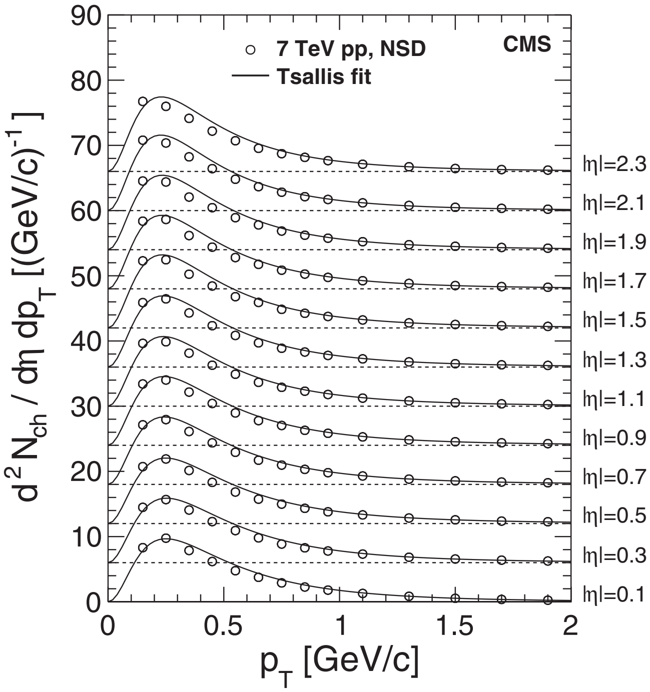

FIG. 1. Differential yield of charged hadrons in the range $|\eta| < 2.4$ in 0.2-unit-wide bins of $|\eta|$ in NSD events. The solid curves represent fits of Eq. (1) to the data. The measurements with increasing η are successively shifted by six units along the vertical axis.

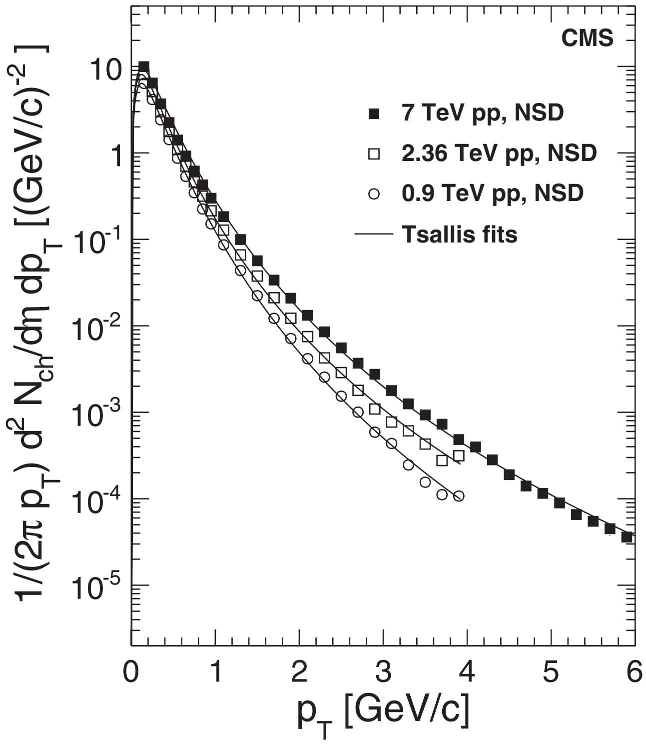

FIG. 2. Charged-hadron yield in the range $|\eta| < 2.4$ in NSD events as a function of p_T; the systematic uncertainties are smaller than the symbols. The measurements at $\sqrt{s} = 0.9$ and 2.36 TeV [3] are also shown. The solid lines represent fits of Eq. (1) to the data.

at 0.9, 2.36, and 7 TeV. The high-p_T reach of the data is limited by the increase of systematic uncertainties with p_T. The fit to the data [Eq. (1)] is mainly used for extrapolations to $p_T = 0$, but is not expected to give a good description of the data in all η bins with only two parameters. The parameter T and the exponent n were found to be $T = 0.145 \pm 0.005(\text{syst})$ GeV and $n = 6.6 \pm 0.2(\text{syst})$. The average p_T, calculated from a combination of the measured data points and the low- and high-p_T contributions as determined from the fit, is $\langle p_T \rangle = 0.545 \pm 0.005(\text{stat}) \pm 0.015(\text{syst})$ GeV$/c$.

Experimental uncertainties related to the trigger and event selection are common to all the analysis methods. The uncertainty related to the presence of SD (DD) events in the final sample was estimated to be 1.4% (1.1%), based on consistency checks between data and simulation for diffractive event candidates. The total event selection uncertainty, which also includes the selection efficiency of the BSC and HF, was found to be 3.5%. Based on studies similar to those presented in Ref. [3], additional 3% and 2% uncertainties were assigned to the tracklet and track reconstruction algorithm efficiencies, respectively. Corrections at the percent level were applied to the final results to extrapolate to $p_T = 0$. The uncertainty on these extrapolation corrections was found to be less than 1%. All other uncertainties are identical to those listed in Ref. [3]. The $dN_{\text{ch}}/d\eta$ measurements were repeated on a separate data sample without any magnetic field, for which almost no p_T extrapolation is needed, and gave results consistent within 1.5%. The final systematic uncertainties for the pixel counting, tracklet, and track methods were found to be 5.7%, 4.6%, and 4.3%, respectively, and are strongly correlated.

For the $dN_{\text{ch}}/d\eta$ measurements, the results for the three individual layers within the cluster-counting method were found to be consistent within 1.2% and were combined. The three layer pairs in the pixel-tracklet method provided results that agreed within 0.6% and were also combined. Finally, the results from the three different measurement methods, which agree with the combined result within 1% to 4% depending on η, were averaged. The final $dN_{\text{ch}}/d\eta$ distributions are shown in Fig. 3 for $\sqrt{s} = 0.9$, 2.36, and 7 TeV. The CMS results are compared with measurements made by other experiments. In the ATLAS Collaboration analysis [15], events and particles were selected in a different region of phase space, which makes a direct comparison difficult. Their results are therefore not included in the figure.

The results can also be compared to earlier experiments as a function of $\sqrt{s}$. The energy dependence of the average charged hadron p_T can be described by a quadratic function of $\ln s$ [16]. As shown in Fig. 4, the present measure-

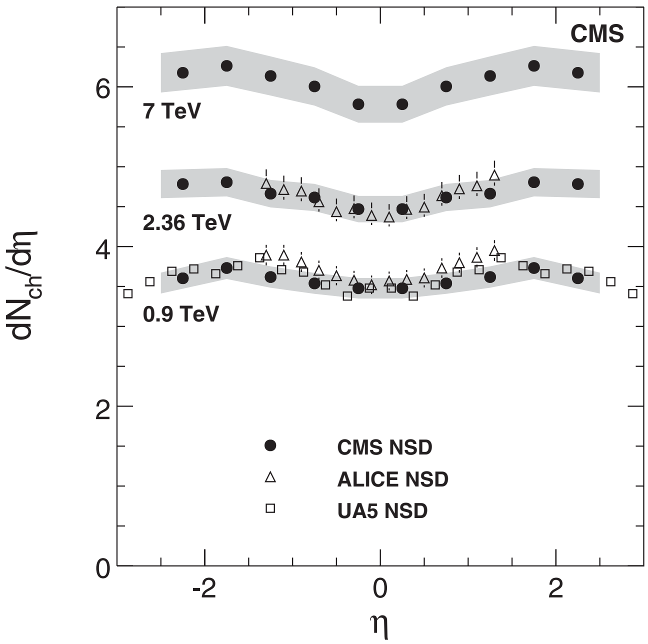

FIG. 3. Distributions of $dN_{\mathrm{ch}}/d\eta$, averaged over the three measurement methods and compared with data from UA5 [23] ($p\bar{p}$, with statistical errors only) and ALICE [24] (with systematic uncertainties). The shaded band shows systematic uncertainties of the CMS data. The CMS and UA5 data are averaged over negative and positive values of η.

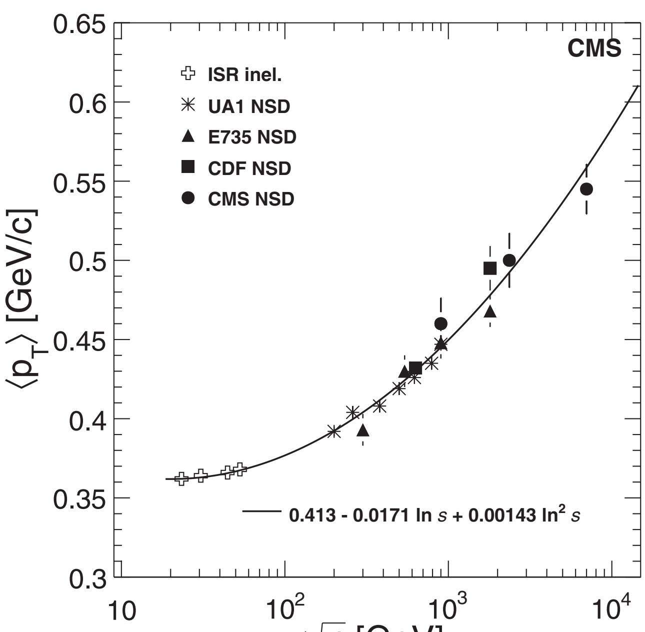

FIG. 4. Average p_T of charged hadrons as a function of the center-of-mass energy. The CMS measurements are for $|\eta| < 2.4$. Also shown are measurements from the ISR [25] (pp), E735 [26] ($p\bar{p}$), and CDF [27] ($p\bar{p}$) for $|\eta| < 0.5$, and from UA1 [16] ($p\bar{p}$) for $|\eta| < 2.5$. The solid line is a fit of the functional form $\langle p_T \rangle = 0.413 - 0.0171 \ln s + 0.001\,43 \ln^2 s$ to the data. The error bars on the CMS data include the systematic uncertainties.

ment follows this trend. The choice of the $|\eta|$ interval can influence the average p_T value by a few percent.

For $|\eta| < 0.5$, the average charged multiplicity density is $dN_{\mathrm{ch}}/d\eta = 5.78 \pm 0.01(\mathrm{stat}) \pm 0.23(\mathrm{syst})$ for NSD events. The $\sqrt{s}$ dependence of the measured $dN_{\mathrm{ch}}/d\eta|_{\eta\approx 0}$ is shown in Fig. 5, which includes data from various other experiments. The $dN_{\mathrm{ch}}/d\eta$ results reported here show a rather steep increase between 0.9 and 7 TeV, which is measured to be $[66.1 \pm 1.0(\mathrm{stat}) \pm 4.2(\mathrm{syst})]\%$. Using a somewhat different event selection, the ALICE Collaboration has found a similar increase of $[57.6 \pm 0.4(\mathrm{stat})^{+3.6}_{-1.8}(\mathrm{syst})]\%$ [5]. The measured charged-particle multiplicity is accurate enough to distinguish among most sets of event-generator tuning parameter values and various models. The measured value at 7 TeV significantly exceeds the prediction of 4.57 from PHOJET [9,10], and the predictions of 3.99, 4.18, and 4.34 from the DW [17], PROQ20 [18], and Perugia0 [19] tuning parameter values of PYTHIA, respectively, while it is closer to the prediction of 5.48 from the PYTHIA parameter set from Ref. [8] and to the recent model predictions of 5.58 and 5.78 from Refs. [20,21]. The measured excess of the number of charged hadrons with respect to the event generators is independent of η and concentrated in the $p_T < 1$ GeV/c

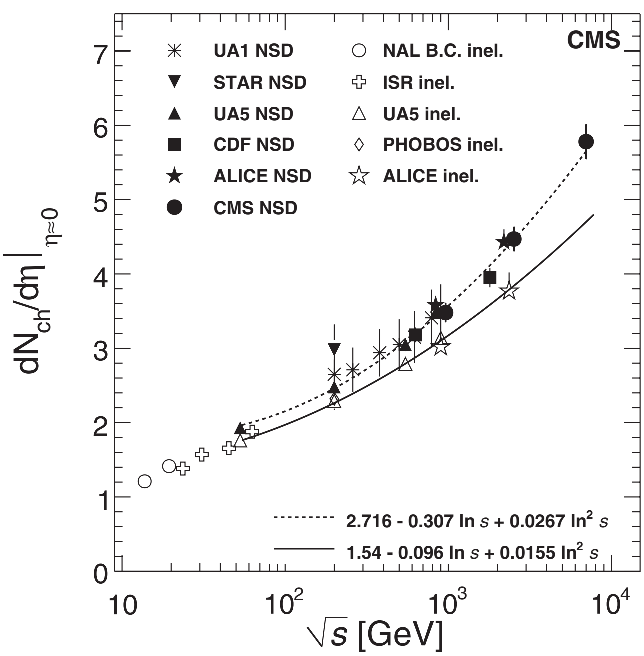

FIG. 5. Average value of $dN_{\mathrm{ch}}/d\eta$ in the central η region as a function of center-of-mass energy in pp and $p\bar{p}$ collisions. Also shown are NSD and inelastic measurements from the NAL Bubble Chamber [28] ($p\bar{p}$), ISR [29] (pp), UA1 [16] ($p\bar{p}$), UA5 [23] ($p\bar{p}$), CDF [30] ($p\bar{p}$), STAR [31] (pp), PHOBOS [32] (pp), and ALICE [24] (pp). The curves are second-order polynomial fits for the inelastic (solid) and NSD event selections (dashed). The error bars include systematic uncertainties, when available. Data points at 0.9 and 2.36 TeV are slightly displaced horizontally for visibility.

range. These differences indicate the need for a continued model development and simulation tuning. Work on updated event generators based on LHC data is currently under way.

Summary.—Charged-hadron transverse-momentum and pseudorapidity distributions have been measured in proton-proton collisions at $\sqrt{s} = 7$ TeV. The numerical values of the data presented in this Letter can be found in the HEPDATA database [22]. The combined result for the central pseudorapidity density, from three mutually consistent methods of measurement, is $dN_{\rm ch}/d\eta|_{|\eta|<0.5} = 5.78 \pm 0.01({\rm stat}) \pm 0.23({\rm syst})$ for non-single-diffractive events. This value is higher than most predictions and provides new information to constrain ongoing improvements of soft particle production models and event generators. The mean transverse momentum has been measured to be $0.545 \pm 0.005({\rm stat}) \pm 0.015({\rm syst})$ GeV/c. These studies are the first steps in the exploration of particle production at the new center-of-mass energy frontier, and contribute to the understanding of the dynamics in soft hadronic interactions.

We congratulate and express our gratitude to our colleagues in the CERN accelerator departments for the excellent performance of the LHC. We thank the technical and administrative staff at CERN and other CMS institutes, and acknowledge support from the following: FMSR (Austria); FNRS and FWO (Belgium); CNPq, CAPES, FAPERJ, and FAPESP (Brazil); MES (Bulgaria); CERN; CAS, MoST, and NSFC (China); COLCIENCIAS (Colombia); MSES (Croatia); RPF (Cyprus); Academy of Sciences and NICPB (Estonia); Academy of Finland, ME, and HIP (Finland); CEA and CNRS/IN2P3 (France); BMBF, DFG, and HGF (Germany); GSRT (Greece); OTKA and NKTH (Hungary); DAE and DST (India); IPM (Iran); SFI (Ireland); INFN (Italy); NRF and WCU (Korea); LAS (Lithuania); CINVESTAV, CONACYT, SEP, and UASLP-FAI (Mexico); PAEC (Pakistan); SCSR (Poland); FCT (Portugal); JINR (Armenia, Belarus, Georgia, Ukraine, Uzbekistan); MST and MAE (Russia); MSTDS (Serbia); MICINN and CPAN (Spain); Swiss Funding Agencies (Switzerland); NSC (Taipei); TUBITAK and TAEK (Turkey); STFC (U.K.); DOE and NSF (U.S.).

[1] L. Evans and P. Bryant, JINST **3**, S08001 (2008).
[2] W. Kittel and E. A. DeWolf, *Soft Multihadron Dynamics* (World Scientic, Singapore, 2005), ISBN 981-256-295-8.
[3] V. Khachatryan *et al.* (CMS Collaboration), J. High Energy Phys. 02 (2010) 041.
[4] S. Chatrchyan *et al.* (CMS Collaboration), JINST **3**, S08004 (2008).
[5] K. Aamodt *et al.* (ALICE Collaboration), arXiv:1004.3514.
[6] S. Agostinelli *et al.* (GEANT4 Collaboration), Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).
[7] T. Sjöstrand, S. Mrenna, and P. Skands, J. High Energy Phys. 05 (2006) 026.
[8] A. Moraes, C. Buttar, and I. Dawson, Eur. Phys. J. C **50**, 435 (2007).
[9] F. W. Bopp, R. Engel, and J. Ranft, arXiv:hepph/9803437.
[10] R. Engel, J. Ranft, and S. Roesler, Phys. Rev. D **52**, 1459 (1995).
[11] F. Siklér, Nucl. Instrum. Methods Phys. Res., Sect. A (in press).
[12] C. Tsallis, J. Stat. Phys. **52**, 479 (1988).
[13] G. Wilk and Z. Włodarczyk, Eur. Phys. J. A **40**, 299 (2009).
[14] T. S. Biró, G. Purcsel, and K. Ürmössy, Eur. Phys. J. A **40**, 325 (2009).
[15] G. Aad *et al.* (ATLAS Collaboration), Phys. Lett. B **688**, 21 (2010).
[16] C. Albajar *et al.* (UA1 Collaboration), Nucl. Phys. **B335**, 261 (1990).
[17] R. Bernhard *et al.*, in Proceedings of the First International Workshop on Multiple Partonic Interactions at the LHC MPI'08, Perugia, Italy, 2008, edited by P. Bartalini and L. Fanó (arXiv:1003.4220).
[18] A. Buckley *et al.*, Eur. Phys. J. C **65**, 331 (2010).
[19] P. Z. Skands, arXiv:0905.3418.
[20] E. Levin and A. H. Rezaeian, arXiv:1005.0631.
[21] A. K. Likhoded, A. V. Luchinsky, and A. A. Novoselov, arXiv:1005.1827.
[22] Available at HEPDATA, http://hepdata.cedar.ac.uk/view/irn8656010.
[23] G. J. Alner *et al.* (UA5 Collaboration), Z. Phys. C **33**, 1 (1986).
[24] K. Aamodt *et al.* (ALICE Collaboration), arXiv:1004.3034 [Eur. Phys. J. C (to be published)].
[25] A. M. Rossi *et al.*, Nucl. Phys. **B84**, 269 (1975).
[26] T. Alexopoulos *et al.* (E735 Collaboration), Phys. Rev. Lett. **60**, 1622 (1988).
[27] F. Abe *et al.* (CDF Collaboration), Phys. Rev. Lett. **61**, 1819 (1988).
[28] J. Whitmore, Phys. Rep. **10**, 273 (1974).
[29] W. Thomé *et al.* (Aachen-CERN-Heidelberg-Munich Collaboration), Nucl. Phys. **B129**, 365 (1977).
[30] F. Abe *et al.* (CDF Collaboration), Phys. Rev. D **41**, 2330 (1990).
[31] B. I. Abelev *et al.* (STAR Collaboration), Phys. Rev. C **79**, 034909 (2009).
[32] R. Nouicer *et al.* (PHOBOS Collaboration), J. Phys. G **30**, S1133 (2004).

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De Favereau De Jeneret,[8] C. Delaere,[8] P. Demin,[8] D. Favart,[8] A. Giammanco,[8] G. Grégoire,[8] J. Hollar,[8] V. Lemaitre,[8] O. Militaru,[8] S. Ovyn,[8] D. Pagano,[8] A. Pin,[8] K. Piotrzkowski,[8,b] L. Quertenmont,[8] N. Schul,[8] N. Beliy,[9] T. Caebergs,[9] E. Daubie,[9] G. A. Alves,[10] M. E. Pol,[10] M. H. G. Souza,[10] W. Carvalho,[11] E. M. Da Costa,[11] D. De Jesus Damiao,[11] C. De Oliveira Martins,[11] S. Fonseca De Souza,[11] L. Mundim,[11] V. Oguri,[11] A. Santoro,[11] S. M. Silva Do Amaral,[11] A. Sznajder,[11] F. Torres Da Silva De Araujo,[11] F. A. Dias,[12] M. A. F. Dias,[12] T. R. Fernandez Perez Tomei,[12] E. M. Gregores,[12] F. Marinho,[12] S. F. Novaes,[12] Sandra S. Padula,[12] N. Darmenov,[13,b] L. Dimitrov,[13] V. Genchev,[13,b] P. Iaydjiev,[13] S. Piperov,[13] S. Stoykova,[13] G. Sultanov,[13] R. Trayanov,[13] I. Vankov,[13] M. Dyulendarova,[14] R. Hadjiiska,[14] V. Kozhuharov,[14] L. Litov,[14] E. Marinova,[14] M. Mateev,[14] B. Pavlov,[14] P. Petkov,[14] J. G. Bian,[15] G. M. Chen,[15] H. S. Chen,[15] C. H. Jiang,[15] D. Liang,[15] S. Liang,[15] J. Wang,[15] J. Wang,[15] X. Wang,[15] Z. Wang,[15] M. Yang,[15] J. Zang,[15] Z. Zhang,[15] Y. Ban,[16] S. Guo,[16] Z. Hu,[16] Y. Mao,[16] S. J. Qian,[16] H. Teng,[16] B. Zhu,[16] A. Cabrera,[17] C. A. Carrillo Montoya,[17] B. Gomez Moreno,[17] A. A. Ocampo Rios,[17] A. F. Osorio Oliveros,[17] J. C. Sanabria,[17] N. Godinovic,[18] D. Lelas,[18] K. Lelas,[18] R. Plestina,[18,c] D. Polic,[18] I. Puljak,[18] Z. Antunovic,[19] M. Dzelalija,[19] V. Brigljevic,[20] S. Duric,[20] K. Kadija,[20] S. Morovic,[20] A. Attikis,[21] R. Fereos,[21] M. Galanti,[21] J. Mousa,[21] C. Nicolaou,[21] A. Papadakis,[21] F. Ptochos,[21] P. A. Razis,[21] H. Rykaczewski,[21] D. Tsiakkouri,[21] Z. Zinonos,[21] M. Mahmoud,[22] A. Hektor,[23] M. Kadastik,[23] K. Kannike,[23] M. Müntel,[23] M. Raidal,[23] L. Rebane,[23] V. Azzolini,[24] P. Eerola,[24] S. Czellar,[25] J. Härkönen,[25] A. Heikkinen,[25] V. Karimäki,[25] R. Kinnunen,[25] J. Klem,[25] M. J. Kortelainen,[25] T. Lampén,[25] K. Lassila-Perini,[25] S. Lehti,[25] T. Lindén,[25] P. Luukka,[25] T. Mäenpää,[25] E. Tuominen,[25] J. Tuominiemi,[25] E. Tuovinen,[25] D. Ungaro,[25] L. Wendland,[25] K. Banzuzi,[26] A. Korpela,[26] T. Tuuva,[26] D. Sillou,[27] M. Besancon,[28] M. Dejardin,[28] D. Denegri,[28] J. Descamps,[28] B. Fabbro,[28] J. L. Faure,[28] F. Ferri,[28] S. Ganjour,[28] F. X. Gentit,[28] A. Givernaud,[28] P. Gras,[28] G. Hamel de Monchenault,[28] P. Jarry,[28] E. Locci,[28] J. Malcles,[28] M. Marionneau,[28] L. Millischer,[28] J. Rander,[28] A. Rosowsky,[28] D. Rousseau,[28] M. Titov,[28] P. Verrecchia,[28] S. Baffioni,[29] L. Bianchini,[29] M. Bluj,[29,d] C. Broutin,[29] P. Busson,[29] C. Charlot,[29] L. Dobrzynski,[29] S. Elgammal,[29] R. Granier de Cassagnac,[29] M. Haguenauer,[29] A. Kalinowski,[29] P. Miné,[29] P. Paganini,[29] D. Sabes,[29] Y. Sirois,[29] C. Thiebaux,[29] A. Zabi,[29] J.-L. Agram,[30] A. Besson,[30] D. Bloch,[30] D. Bodin,[30] J.-M. Brom,[30] M. Cardaci,[30] E. Conte,[30] F. Drouhin,[30] C. Ferro,[30] J.-C. Fontaine,[30] D. Gelé,[30] U. Goerlach,[30] S. Greder,[30] P. Juillot,[30] M. Karim,[30] A.-C. Le Bihan,[30] Y. Mikami,[30] J. Speck,[30] P. Van Hove,[30] F. Fassi,[31] D. Mercier,[31] C. Baty,[32] N. Beaupere,[32] M. Bedjidian,[32] O. Bondu,[32] G. Boudoul,[32] D. Boumediene,[32] H. Brun,[32] N. Chanon,[32] R. Chierici,[32] D. Contardo,[32] P. Depasse,[32] H. El Mamouni,[32] J. Fay,[32] S. Gascon,[32] B. Ille,[32] T. Kurca,[32] T. Le Grand,[32] M. Lethuillier,[32] L. Mirabito,[32] S. Perries,[32] S. Tosi,[32] Y. Tschudi,[32] P. Verdier,[32] H. Xiao,[32] V. Roinishvili,[33] G. Anagnostou,[34] M. Edelhoff,[34] L. Feld,[34] N. Heracleous,[34] O. Hindrichs,[34] R. Jussen,[34] K. Klein,[34] J. Merz,[34] N. Mohr,[34] A. Ostapchuk,[34] A. Perieanu,[34] F. Raupach,[34] J. Sammet,[34] S. Schael,[34] D. Sprenger,[34] H. Weber,[34] M. Weber,[34] B. Wittmer,[34] O. Actis,[35] M. Ata,[35] W. Bender,[35] P. Biallass,[35] M. Erdmann,[35] J. Frangenheim,[35] T. Hebbeker,[35] A. Hinzmann,[35] K. Hoepfner,[35] C. Hof,[35] M. Kirsch,[35] T. Klimkovich,[35] P. Kreuzer,[35,b] D. Lanske,[35,a] C. Magass,[35] M. Merschmeyer,[35] A. Meyer,[35] P. Papacz,[35] H. Pieta,[35] H. Reithler,[35] S. A. Schmitz,[35] L. Sonnenschein,[35] M. Sowa,[35] J. Steggemann,[35] D. Teyssier,[35] C. Zeidler,[35] M. Bontenackels,[36] M. Davids,[36] M. Duda,[36] G. Flügge,[36] H. Geenen,[36] M. Giffels,[36] W. Haj Ahmad,[36] D. Heydhausen,[36] T. Kress,[36] Y. Kuessel,[36] A. Linn,[36] A. Nowack,[36] L. Perchalla,[36] O. Pooth,[36] P. Sauerland,[36] A. Stahl,[36] M. Thomas,[36] D. Tornier,[36] M. H. Zoeller,[36] M. Aldaya Martin,[37] W. Behrenhoff,[37] U. Behrens,[37] M. Bergholz,[37] K. Borras,[37] A. Campbell,[37] E. Castro,[37] D. Dammann,[37] G. Eckerlin,[37] A. Flossdorf,[37] G. Flucke,[37] A. Geiser,[37] J. Hauk,[37] H. Jung,[37] M. Kasemann,[37] I. Katkov,[37] C. Kleinwort,[37] H. Kluge,[37] A. Knutsson,[37] E. Kuznetsova,[37] W. Lange,[37] W. Lohmann,[37] R. Mankel,[37] M. Marienfeld,[37] I.-A. Melzer-Pellmann,[37] A. B. Meyer,[37] J. Mnich,[37] A. Mussgiller,[37] J. Olzem,[37] A. Parenti,[37] A. Raspereza,[37] R. Schmidt,[37] T. Schoerner-Sadenius,[37] N. Sen,[37] M. Stein,[37] J. Tomaszewska,[37] D. Volyanskyy,[37] C. Wissing,[37] C. Autermann,[38]

J. Draeger,[38] D. Eckstein,[38] H. Enderle,[38] U. Gebbert,[38] K. Kaschube,[38] G. Kaussen,[38] R. Klanner,[38] B. Mura,[38] S. Naumann-Emme,[38] F. Nowak,[38] C. Sander,[38] H. Schettler,[38] P. Schleper,[38] M. Schröder,[38] T. Schum,[38] J. Schwandt,[38] H. Stadie,[38] G. Steinbrück,[38] J. Thomsen,[38] R. Wolf,[38] J. Bauer,[39] V. Buege,[39] A. Cakir,[39] T. Chwalek,[39] D. Daeuwel,[39] W. De Boer,[39] A. Dierlamm,[39] G. Dirkes,[39] M. Feindt,[39] J. Gruschke,[39] C. Hackstein,[39] F. Hartmann,[39] M. Heinrich,[39] H. Held,[39] K. H. Hoffmann,[39] S. Honc,[39] T. Kuhr,[39] D. Martschei,[39] S. Mueller,[39] Th. Müller,[39] M. Niegel,[39] O. Oberst,[39] A. Oehler,[39] J. Ott,[39] T. Peiffer,[39] D. Piparo,[39] G. Quast,[39] K. Rabbertz,[39] F. Ratnikov,[39] M. Renz,[39] A. Sabellek,[39] C. Saout,[39,b] A. Scheurer,[39] P. Schieferdecker,[39] F.-P. Schilling,[39] G. Schott,[39] H. J. Simonis,[39] F. M. Stober,[39] D. Troendle,[39] J. Wagner-Kuhr,[39] M. Zeise,[39] V. Zhukov,[39,e] E. B. Ziebarth,[39] G. Daskalakis,[40] T. Geralis,[40] A. Kyriakis,[40] D. Loukas,[40] I. Manolakos,[40] A. Markou,[40] C. Markou,[40] C. Mavrommatis,[40] E. Petrakou,[40] L. Gouskos,[41] P. Katsas,[41] A. Panagiotou,[41,b] I. Evangelou,[42] P. Kokkas,[42] N. Manthos,[42] I. Papadopoulos,[42] V. Patras,[42] F. A. Triantis,[42] A. Aranyi,[43] G. Bencze,[43] L. Boldizsar,[43] G. Debreczeni,[43] C. Hajdu,[43,b] D. Horvath,[43,f] A. Kapusi,[43] K. Krajczar,[43] A. Laszlo,[43] F. Sikler,[43] G. Vesztergombi,[43] N. Beni,[44] J. Molnar,[44] J. Palinkas,[44] Z. Szillasi,[44,b] V. Veszpremi,[44] P. Raics,[45] Z. L. Trocsanyi,[45] B. Ujvari,[45] S. Bansal,[46] S. B. Beri,[46] V. Bhatnagar,[46] M. Jindal,[46] M. Kaur,[46] J. M. Kohli,[46] M. Z. Mehta,[46] N. Nishu,[46] L. K. Saini,[46] A. Sharma,[46] R. Sharma,[46] A. P. Singh,[46] J. B. Singh,[46] S. P. Singh,[46] S. Ahuja,[47] S. Bhattacharya,[47,g] S. Chauhan,[47] B. C. Choudhary,[47] P. Gupta,[47] S. Jain,[47] S. Jain,[47] A. Kumar,[47] K. Ranjan,[47] R. K. Shivpuri,[47] R. K. Choudhury,[48] D. Dutta,[48] S. Kailas,[48] S. K. Kataria,[48] A. K. Mohanty,[48] L. M. Pant,[48] P. Shukla,[48] P. Suggisetti,[48] T. Aziz,[49] M. Guchait,[49,h] A. Gurtu,[49] M. Maity,[49] D. Majumder,[49] G. Majumder,[49] K. Mazumdar,[49] G. B. Mohanty,[49] A. Saha,[49] K. Sudhakar,[49] N. Wickramage,[49] S. Banerjee,[50] S. Dugad,[50] N. K. Mondal,[50] H. Arfaei,[51] H. Bakhshiansohi,[51] A. Fahim,[51] A. Jafari,[51] M. Mohammadi Najafabadi,[51] S. Paktinat Mehdiabadi,[51] B. Safarzadeh,[51] M. Zeinali,[51] M. Abbrescia,[52a,52b] L. Barbone,[52a] A. Colaleo,[52a] D. Creanza,[52a,52c] N. De Filippis,[52a] M. De Palma,[52a,52b] A. Dimitrov,[52a] F. Fedele,[52a] L. Fiore,[52a] G. Iaselli,[52a,52c] L. Lusito,[52a,52b,b] G. Maggi,[52a,52c] M. Maggi,[52a] N. Manna,[52a,52b] B. Marangelli,[52a,52b] S. My,[52a,52c] S. Nuzzo,[52a,52b] G. A. Pierro,[52a] A. Pompili,[52a,52b] G. Pugliese,[52a,52c] F. Romano,[52a,52c] G. Roselli,[52a,52b] G. Selvaggi,[52a,52b] L. Silvestris,[52a] R. Trentadue,[52a] S. Tupputi,[52a,52b] G. Zito,[52a] G. Abbiendi,[53a] A. C. Benvenuti,[53a] D. Bonacorsi,[53a] S. Braibant-Giacomelli,[53a,53b] A. Castro,[53a,53b] F. R. Cavallo,[53a] G. Codispoti,[53a,53b] G. M. Dallavalle,[53a,b] F. Fabbri,[53a] A. Fanfani,[53a,53b] D. Fasanella,[53a] P. Giacomelli,[53a] M. Giunta,[53a,b] C. Grandi,[53a] S. Marcellini,[53a] G. Masetti,[53a,53b] A. Montanari,[53a] F. L. Navarria,[53a,53b] F. Odorici,[53a] A. Perrotta,[53a] A. M. Rossi,[53a,53b] T. Rovelli,[53a,53b] G. Siroli,[53a,53b] R. Travaglini,[53a,53b] S. Albergo,[54a,54b] G. Cappello,[54a,54b] M. Chiorboli,[54a,54b] S. Costa,[54a,54b] A. Tricomi,[54a,54b] C. Tuve,[54a] G. Barbagli,[55a] G. Broccolo,[55a,55b] V. Ciulli,[55a,55b] C. Civinini,[55a] R. D'Alessandro,[55a,55b] E. Focardi,[55a,55b] S. Frosali,[55a,55b] E. Gallo,[55a] C. Genta,[55a,55b] P. Lenzi,[55a,55b,b] M. Meschini,[55a] S. Paoletti,[55a] G. Sguazzoni,[55a] A. Tropiano,[55a] L. Benussi,[56] S. Bianco,[56] S. Colafranceschi,[56] F. Fabbri,[56] D. Piccolo,[56] P. Fabbricatore,[57] R. Musenich,[57] A. Benaglia,[58a,58b] G. B. Cerati,[58a,58b,b] F. De Guio,[58a,58b] L. Di Matteo,[58a,58b] A. Ghezzi,[58a,58b,b] P. Govoni,[58a,58b] M. Malberti,[58a,58b,b] S. Malvezzi,[58a] A. Martelli,[58a,58b,c] A. Massironi,[58a,58b] D. Menasce,[58a] V. Miccio,[58a,58b] L. Moroni,[58a] P. Negri,[58a,58b] M. Paganoni,[58a,58b] D. Pedrini,[58a] S. Ragazzi,[58a,58b] N. Redaelli,[58a] S. Sala,[58a] R. Salerno,[58a,58b] T. Tabarelli de Fatis,[58a,58b] V. Tancini,[58a,58b] S. Taroni,[58a,58b] S. Buontempo,[59a] A. Cimmino,[59a,59b] A. De Cosa,[59a,59b,b] M. De Gruttola,[59a,59b,b] F. Fabozzi,[59a] A. O. M. Iorio,[59a] L. Lista,[59a] P. Noli,[59a,59b] P. Paolucci,[59a] P. Azzi,[60a] N. Bacchetta,[60a] P. Bellan,[60a,60b,b] M. Bellato,[60a] M. Biasotto,[60a] D. Bisello,[60a,60b] R. Carlin,[60a,60b] P. Checchia,[60a] M. De Mattia,[60a,60b] T. Dorigo,[60a] F. Fanzago,[60a] F. Gasparini,[60a,60b] P. Giubilato,[60a,60b] A. Gresele,[60a,60c] S. Lacaprara,[60a] I. Lazzizzera,[60a,60c] M. Margoni,[60a,60b] G. Maron,[60a] A. T. Meneguzzo,[60a,60b] M. Nespolo,[60a] L. Perrozzi,[60a] N. Pozzobon,[60a,60b] P. Ronchese,[60a,60b] F. Simonetto,[60a,60b] E. Torassa,[60a] M. Tosi,[60a,60b] A. Triossi,[60a] S. Vanini,[60a,60b] G. Zumerle,[60a,60b] P. Baesso,[61a,61b] U. Berzano,[61a] C. Riccardi,[61a,61b] P. Torre,[61a,61b] P. Vitulo,[61a,61b] C. Viviani,[61a,61b] M. Biasini,[62a,62b] G. M. Bilei,[62a] B. Caponeri,[62a,62b] L. Fanò,[62a] P. Lariccia,[62a,62b] A. Lucaroni,[62a,62b] G. Mantovani,[62a,62b] M. Menichelli,[62a] A. Nappi,[62a,62b] A. Santocchia,[62a,62b] L. Servoli,[62a] M. Valdata,[62a] R. Volpe,[62a,62b,b] P. Azzurri,[63a,63c] G. Bagliesi,[63a] J. Bernardini,[63a,63b,b] T. Boccali,[63a] R. Castaldi,[63a] R. T. Dagnolo,[63a,63c] R. Dell'Orso,[63a] F. Fiori,[63a,63b] L. Foà,[63a,63c] A. Giassi,[63a] A. Kraan,[63a] F. Ligabue,[63a,63c] T. Lomtadze,[63a] L. Martini,[63a] A. Messineo,[63a,63b] F. Palla,[63a] F. Palmonari,[63a] G. Segneri,[63a] A. T. Serban,[63a] P. Spagnolo,[63a,b] R. Tenchini,[63a,b] G. Tonelli,[63a,63b,b] A. Venturi,[63a] P. G. Verdini,[63a] L. Barone,[64a,64b] F. Cavallari,[64a,b] D. Del Re,[64a,64b] E. Di Marco,[64a,64b] M. Diemoz,[64a] D. Franci,[64a,64b] M. Grassi,[64a] E. Longo,[64a,64b] G. Organtini,[64a,64b] A. Palma,[64a,64b] F. Pandolfi,[64a,64b] R. Paramatti,[64a,b] S. Rahatlou,[64a,64b,b] N. Amapane,[65a,65b]

R. Arcidiacono,[65a,65b] S. Argiro,[65a,65b] M. Arneodo,[65a,65c] C. Biino,[65a] C. Botta,[65a,65b] N. Cartiglia,[65a] R. Castello,[65a,65b] M. Costa,[65a,65b] N. Demaria,[65a] A. Graziano,[65a,65b] C. Mariotti,[65a] M. Marone,[65a,65b] S. Maselli,[65a] E. Migliore,[65a,65b] G. Mila,[65a,65b] V. Monaco,[65a,65b] M. Musich,[65a,65b] M. M. Obertino,[65a,65c] N. Pastrone,[65a] M. Pelliccioni,[65a,65b,b] A. Romero,[65a,65b] M. Ruspa,[65a,65c] R. Sacchi,[65a,65b] A. Solano,[65a,65b] A. Staiano,[65a] D. Trocino,[65a,65b] A. Vilela Pereira,[65a,65b,b] F. Ambroglini,[66a,66b] S. Belforte,[66a] F. Cossutti,[66a] G. Della Ricca,[66a,66b] B. Gobbo,[66a] D. Montanino,[66a] A. Penzo,[66a] S. Chang,[67] J. Chung,[67] D. H. Kim,[67] G. N. Kim,[67] J. E. Kim,[67] D. J. Kong,[67] H. Park,[67] D. C. Son,[67] Zero Kim,[68] J. Y. Kim,[68] S. Song,[68] B. Hong,[69] H. Kim,[69] J. H. Kim,[69] T. J. Kim,[69] K. S. Lee,[69] D. H. Moon,[69] S. K. Park,[69] H. B. Rhee,[69] K. S. Sim,[69] M. Choi,[70] S. Kang,[70] H. Kim,[70] C. Park,[70] I. C. Park,[70] S. Park,[70] S. Choi,[71] Y. Choi,[71] Y. K. Choi,[71] J. Goh,[71] J. Lee,[71] S. Lee,[71] H. Seo,[71] I. Yu,[71] M. Janulis,[72] D. Martisiute,[72] P. Petrov,[72] T. Sabonis,[72] H. Castilla Valdez,[73,b] E. De La Cruz Burelo,[73] R. Lopez-Fernandez,[73] A. Sánchez Hernández,[73] L. M. Villaseñor-Cendejas,[73] S. Carrillo Moreno,[74] H. A. Salazar Ibarguen,[75] E. Casimiro Linares,[76] A. Morelos Pineda,[76] M. A. Reyes-Santos,[76] P. Allfrey,[77] D. Krofcheck,[77] J. Tam,[77] T. Aumeyr,[78] P. H. Butler,[78] T. Signal,[78] J. C. Williams,[78] M. Ahmad,[79] I. Ahmed,[79] M. I. Asghar,[79] H. R. Hoorani,[79] W. A. Khan,[79] T. Khurshid,[79] S. Qazi,[79] M. Cwiok,[80] W. Dominik,[80] K. Doroba,[80] M. Konecki,[80] J. Krolikowski,[80] T. Frueboes,[81] R. Gokieli,[81] M. Górski,[81] M. Kazana,[81] K. Nawrocki,[81] M. Szleper,[81] G. Wrochna,[81] P. Zalewski,[81] N. Almeida,[82] A. David,[82] P. Faccioli,[82] P. G. Ferreira Parracho,[82] M. Gallinaro,[82] G. Mini,[82] P. Musella,[82] A. Nayak,[82] L. Raposo,[82] P. Q. Ribeiro,[82] J. Seixas,[82] P. Silva,[82] D. Soares,[82] J. Varela,[82,b] H. K. Wöhri,[82] I. Altsybeev,[83] I. Belotelov,[83] P. Bunin,[83] M. Finger,[83] M. Finger, Jr.,[83] I. Golutvin,[83] A. Kamenev,[83] V. Karjavin,[83] G. Kozlov,[83] A. Lanev,[83] P. Moisenz,[83] V. Palichik,[83] V. Perelygin,[83] S. Shmatov,[83] V. Smirnov,[83] A. Volodko,[83] A. Zarubin,[83] N. Bondar,[84] V. Golovtsov,[84] Y. Ivanov,[84] V. Kim,[84] P. Levchenko,[84] I. Smirnov,[84] V. Sulimov,[84] L. Uvarov,[84] S. Vavilov,[84] A. Vorobyev,[84] Yu. Andreev,[85] S. Gninenko,[85] N. Golubev,[85] M. Kirsanov,[85] N. Krasnikov,[85] V. Matveev,[85] A. Pashenkov,[85] A. Toropin,[85] S. Troitsky,[85] V. Epshteyn,[86] V. Gavrilov,[86] N. Ilina,[86] V. Kaftanov,[86,a] M. Kossov,[86,b] A. Krokhotin,[86] S. Kuleshov,[86] A. Oulianov,[86] G. Safronov,[86] S. Semenov,[86] I. Shreyber,[86] V. Stolin,[86] E. Vlasov,[86] A. Zhokin,[86] E. Boos,[87] M. Dubinin,[87,i] L. Dudko,[87] A. Ershov,[87] A. Gribushin,[87] O. Kodolova,[87] I. Lokhtin,[87] S. Obraztsov,[87] S. Petrushanko,[87] L. Sarycheva,[87] V. Savrin,[87] A. Snigirev,[87] V. Andreev,[88] I. Dremin,[88] M. Kirakosyan,[88] S. V. Rusakov,[88] A. Vinogradov,[88] I. Azhgirey,[89] S. Bitioukov,[89] K. Datsko,[89] V. Grishin,[89,b] V. Kachanov,[89] D. Konstantinov,[89] V. Krychkine,[89] V. Petrov,[89] R. Ryutin,[89] S. Slabospitsky,[89] A. Sobol,[89] A. Sytine,[89] L. Tourtchanovitch,[89] S. Troshin,[89] N. Tyurin,[89] A. Uzunian,[89] A. Volkov,[89] P. Adzic,[90] M. Djordjevic,[90] D. Krpic,[90] D. Maletic,[90] J. Milosevic,[90] J. Puzovic,[90] M. Aguilar-Benitez,[91] J. Alcaraz Maestre,[91] P. Arce,[91] C. Battilana,[91] E. Calvo,[91] M. Cepeda,[91] M. Cerrada,[91] M. Chamizo Llatas,[91] N. Colino,[91] B. De La Cruz,[91] C. Diez Pardos,[91] C. Fernandez Bedoya,[91] J. P. Fernández Ramos,[91] A. Ferrando,[91] J. Flix,[91] M. C. Fouz,[91] P. Garcia-Abia,[91] O. Gonzalez Lopez,[91] S. Goy Lopez,[91] J. M. Hernandez,[91] M. I. Josa,[91] G. Merino,[91] J. Puerta Pelayo,[91] I. Redondo,[91] L. Romero,[91] J. Santaolalla,[91] C. Willmott,[91] C. Albajar,[92] J. F. de Trocóniz,[92] J. Cuevas,[93] J. Fernandez Menendez,[93] I. Gonzalez Caballero,[93] L. Lloret Iglesias,[93] J. M. Vizan Garcia,[93] I. J. Cabrillo,[94] A. Calderon,[94] S. H. Chuang,[94] I. Diaz Merino,[94] C. Diez Gonzalez,[94] J. Duarte Campderros,[94] M. Fernandez,[94] G. Gomez,[94] J. Gonzalez Sanchez,[94] R. Gonzalez Suarez,[94] C. Jorda,[94] P. Lobelle Pardo,[94] A. Lopez Virto,[94] J. Marco,[94] R. Marco,[94] C. Martinez Rivero,[94] P. Martinez Ruiz del Arbol,[94] F. Matorras,[94] T. Rodrigo,[94] A. Ruiz Jimeno,[94] L. Scodellaro,[94] M. Sobron Sanudo,[94] I. Vila,[94] R. Vilar Cortabitarte,[94] D. Abbaneo,[95] E. Auffray,[95] P. Baillon,[95] A. H. Ball,[95] D. Barney,[95] F. Beaudette,[95,c] A. J. Bell,[95] R. Bellan,[95] D. Benedetti,[95] C. Bernet,[95,c] W. Bialas,[95] P. Bloch,[95] A. Bocci,[95] S. Bolognesi,[95] H. Breuker,[95] G. Brona,[95] K. Bunkowski,[95] T. Camporesi,[95] E. Cano,[95] A. Cattai,[95] G. Cerminara,[95] T. Christiansen,[95] J. A. Coarasa Perez,[95] R. Covarelli,[95] B. Curé,[95] T. Dahms,[95] A. De Roeck,[95] A. Elliott-Peisert,[95] W. Funk,[95] A. Gaddi,[95] S. Gennai,[95] H. Gerwig,[95] D. Gigi,[95] K. Gill,[95] D. Giordano,[95] F. Glege,[95] R. Gomez-Reino Garrido,[95] S. Gowdy,[95] L. Guiducci,[95] M. Hansen,[95] C. Hartl,[95] J. Harvey,[95] B. Hegner,[95] C. Henderson,[95] H. F. Hoffmann,[95] A. Honma,[95] V. Innocente,[95] P. Janot,[95] P. Lecoq,[95] C. Leonidopoulos,[95] C. Lourenço,[95] A. Macpherson,[95] T. Mäki,[95] L. Malgeri,[95] M. Mannelli,[95] L. Masetti,[95] G. Mavromanolakis,[95] F. Meijers,[95] S. Mersi,[95] E. Meschi,[95] R. Moser,[95] M. U. Mozer,[95] M. Mulders,[95] E. Nesvold,[95,b] L. Orsini,[95] E. Perez,[95] A. Petrilli,[95] A. Pfeiffer,[95] M. Pierini,[95] M. Pimiä,[95] A. Racz,[95] G. Rolandi,[95] C. Rovelli,[95,j] M. Rovere,[95] V. Ryjov,[95] H. Sakulin,[95] C. Schäfer,[95] C. Schwick,[95] I. Segoni,[95] A. Sharma,[95] P. Siegrist,[95] M. Simon,[95] P. Sphicas,[95,k] D. Spiga,[95] M. Spiropulu,[95,i] F. Stöckli,[95] P. Traczyk,[95] P. Tropea,[95] A. Tsirou,[95] G. I. Veres,[95] P. Vichoudis,[95] M. Voutilainen,[95] W. D. Zeuner,[95] W. Bertl,[96] K. Deiters,[96] W. Erdmann,[96]

K. Gabathuler,[96] R. Horisberger,[96] Q. Ingram,[96] H. C. Kaestli,[96] S. König,[96] D. Kotlinski,[96] U. Langenegger,[96] F. Meier,[96] D. Renker,[96] T. Rohe,[96] J. Sibille,[96,l] A. Starodumov,[96,m] L. Caminada,[97,n] Z. Chen,[97] S. Cittolin,[97] G. Dissertori,[97] M. Dittmar,[97] J. Eugster,[97] K. Freudenreich,[97] C. Grab,[97] A. Hervé,[97] W. Hintz,[97] P. Lecomte,[97] W. Lustermann,[97] C. Marchica,[97,n] P. Meridiani,[97] P. Milenovic,[97,o] F. Moortgat,[97] A. Nardulli,[97] F. Nessi-Tedaldi,[97] L. Pape,[97] F. Pauss,[97] T. Punz,[97] A. Rizzi,[97] F. J. Ronga,[97] L. Sala,[97] A. K. Sanchez,[97] M.-C. Sawley,[97] D. Schinzel,[97] V. Sordini,[97] B. Stieger,[97] L. Tauscher,[97,a] A. Thea,[97] K. Theofilatos,[97] D. Treille,[97] M. Weber,[97] L. Wehrli,[97] J. Weng,[97] C. Amsler,[98] V. Chiochia,[98] S. De Visscher,[98] M. Ivova Rikova,[98] B. Millan Mejias,[98] C. Regenfus,[98] P. Robmann,[98] T. Rommerskirchen,[98] A. Schmidt,[98] D. Tsirigkas,[98] L. Wilke,[98] Y. H. Chang,[99] K. H. Chen,[99] W. T. Chen,[99] A. Go,[99] C. M. Kuo,[99] S. W. Li,[99] W. Lin,[99] M. H. Liu,[99] Y. J. Lu,[99] J. H. Wu,[99] S. S. Yu,[99] P. Bartalini,[100] P. Chang,[100] Y. H. Chang,[100] Y. W. Chang,[100] Y. Chao,[100] K. F. Chen,[100] W.-S. Hou,[100] Y. Hsiung,[100] K. Y. Kao,[100] Y. J. Lei,[100] S. W. Lin,[100] R.-S. Lu,[100] J. G. Shiu,[100] Y. M. Tzeng,[100] K. Ueno,[100] C. C. Wang,[100] M. Wang,[100] J. T. Wei,[100] A. Adiguzel,[101] A. Ayhan,[101] M. N. Bakirci,[101] S. Cerci,[101] Z. Demir,[101] C. Dozen,[101] I. Dumanoglu,[101] E. Eskut,[101] S. Girgis,[101] G. Gökbulut,[101] Y. Güler,[101] E. Gurpinar,[101] I. Hos,[101] E. E. Kangal,[101] T. Karaman,[101] A. Kayis Topaksu,[101] A. Nart,[101] G. Önengüt,[101] K. Ozdemir,[101] S. Ozturk,[101] A. Polatöz,[101] O. Sahin,[101] O. Sengul,[101] K. Sogut,[101] B. Tali,[101] H. Topakli,[101] D. Uzun,[101] L. N. Vergili,[101] M. Vergili,[101] C. Zorbilmez,[101] I. V. Akin,[102] T. Aliev,[102] S. Bilmis,[102] M. Deniz,[102] H. Gamsizkan,[102] A. M. Guler,[102] K. Ocalan,[102] A. Ozpineci,[102] M. Serin,[102] R. Sever,[102] U. E. Surat,[102] M. Zeyrek,[102] M. Deliomeroglu,[103] D. Demir,[103] E. Gülmez,[103] A. Halu,[103] B. Isildak,[103] M. Kaya,[103] O. Kaya,[103] M. Özbek,[103] S. Ozkorucuklu,[103] N. Sonmez,[103] L. Levchuk,[104] P. Bell,[105] F. Bostock,[105] J. J. Brooke,[105] T. L. Cheng,[105] D. Cussans,[105] R. Frazier,[105] J. Goldstein,[105] M. Hansen,[105] G. P. Heath,[105] H. F. Heath,[105] C. Hill,[105] B. Huckvale,[105] J. Jackson,[105] L. Kreczko,[105] C. K. Mackay,[105] S. Metson,[105] D. M. Newbold,[105,p] K. Nirunpong,[105] V. J. Smith,[105] S. Ward,[105] L. Basso,[106] K. W. Bell,[106] A. Belyaev,[106] C. Brew,[106] R. M. Brown,[106] B. Camanzi,[106] D. J. A. Cockerill,[106] J. A. Coughlan,[106] K. Harder,[106] S. Harper,[106] B. W. Kennedy,[106] E. Olaiya,[106] B. C. Radburn-Smith,[106] C. H. Shepherd-Themistocleous,[106] I. R. Tomalin,[106] W. J. Womersley,[106] S. D. Worm,[106] R. Bainbridge,[107] G. Ball,[107] J. Ballin,[107] R. Beuselinck,[107] O. Buchmuller,[107] D. Colling,[107] N. Cripps,[107] M. Cutajar,[107] G. Davies,[107] M. Della Negra,[107] C. Foudas,[107] J. Fulcher,[107] D. Futyan,[107] A. Guneratne Bryer,[107] G. Hall,[107] Z. Hatherell,[107] J. Hays,[107] G. Iles,[107] G. Karapostoli,[107] L. Lyons,[107] A.-M. Magnan,[107] J. Marrouche,[107] R. Nandi,[107] J. Nash,[107] A. Nikitenko,[107,m] A. Papageorgiou,[107] M. Pesaresi,[107] K. Petridis,[107] M. Pioppi,[107,q] D. M. Raymond,[107] N. Rompotis,[107] A. Rose,[107] M. J. Ryan,[107] C. Seez,[107] P. Sharp,[107] A. Sparrow,[107] M. Stoye,[107] A. Tapper,[107] S. Tourneur,[107] M. Vazquez Acosta,[107] T. Virdee,[107,b] S. Wakefield,[107] D. Wardrope,[107] T. Whyntie,[107] M. Barrett,[108] M. Chadwick,[108] J. E. Cole,[108] P. R. Hobson,[108] A. Khan,[108] P. Kyberd,[108] D. Leslie,[108] I. D. Reid,[108] L. Teodorescu,[108] T. Bose,[109] A. Clough,[109] A. Heister,[109] J. St. John,[109] P. Lawson,[109] D. Lazic,[109] J. Rohlf,[109] L. Sulak,[109] J. Andrea,[110] A. Avetisyan,[110] S. Bhattacharya,[110] J. P. Chou,[110] D. Cutts,[110] S. Esen,[110] U. Heintz,[110] S. Jabeen,[110] G. Kukartsev,[110] G. Landsberg,[110] M. Narain,[110] D. Nguyen,[110] T. Speer,[110] K. V. Tsang,[110] M. A. Borgia,[111] R. Breedon,[111] M. Calderon De La Barca Sanchez,[111] D. Cebra,[111] M. Chertok,[111] J. Conway,[111] P. T. Cox,[111] J. Dolen,[111] R. Erbacher,[111] E. Friis,[111] W. Ko,[111] A. Kopecky,[111] R. Lander,[111] H. Liu,[111] S. Maruyama,[111] T. Miceli,[111] M. Nikolic,[111] D. Pellett,[111] J. Robles,[111] T. Schwarz,[111] M. Searle,[111] J. Smith,[111] M. Squires,[111] M. Tripathi,[111] R. Vasquez Sierra,[111] C. Veelken,[111] V. Andreev,[112] K. Arisaka,[112] D. Cline,[112] R. Cousins,[112] A. Deisher,[112] S. Erhan,[112,b] C. Farrell,[112] M. Felcini,[112] J. Hauser,[112] M. Ignatenko,[112] C. Jarvis,[112] C. Plager,[112] G. Rakness,[112] P. Schlein,[112,a] J. Tucker,[112] V. Valuev,[112] R. Wallny,[112] J. Babb,[113] R. Clare,[113] J. Ellison,[113] J. W. Gary,[113] G. Hanson,[113] G. Y. Jeng,[113] S. C. Kao,[113] F. Liu,[113] H. Liu,[113] A. Luthra,[113] H. Nguyen,[113] G. Pasztor,[113,r] A. Satpathy,[113] B. C. Shen,[113,a] R. Stringer,[113] J. Sturdy,[113] S. Sumowidagdo,[113] R. Wilken,[113] S. Wimpenny,[113] W. Andrews,[114] J. G. Branson,[114] E. Dusinberre,[114] D. Evans,[114] F. Golf,[114] A. Holzner,[114] R. Kelley,[114] M. Lebourgeois,[114] J. Letts,[114] B. Mangano,[114] J. Muelmenstaedt,[114] S. Padhi,[114] C. Palmer,[114] G. Petrucciani,[114] H. Pi,[114] M. Pieri,[114] R. Ranieri,[114] M. Sani,[114] V. Sharma,[114,b] S. Simon,[114] Y. Tu,[114] A. Vartak,[114] F. Würthwein,[114] A. Yagil,[114] D. Barge,[115] M. Blume,[115] C. Campagnari,[115] M. D'Alfonso,[115] T. Danielson,[115] J. Garberson,[115] J. Incandela,[115] C. Justus,[115] P. Kalavase,[115] S. A. Koay,[115] D. Kovalskyi,[115] V. Krutelyov,[115] J. Lamb,[115] S. Lowette,[115] V. Pavlunin,[115] F. Rebassoo,[115] J. Ribnik,[115] J. Richman,[115] R. Rossin,[115] D. Stuart,[115] W. To,[115] J. R. Vlimant,[115] M. Witherell,[115] A. Bornheim,[116] J. Bunn,[116] M. Gataullin,[116] D. Kcira,[116] V. Litvine,[116] Y. Ma,[116] H. B. Newman,[116] C. Rogan,[116] K. Shin,[116] V. Timciuc,[116] J. Veverka,[116] R. Wilkinson,[116] Y. Yang,[116] R. Y. Zhu,[116] B. Akgun,[117] R. Carroll,[117] T. Ferguson,[117] D. W. Jang,[117] S. Y. Jun,[117] M. Paulini,[117]

J. Russ,[117] N. Terentyev,[117] H. Vogel,[117] I. Vorobiev,[117] J. P. Cumalat,[118] M. E. Dinardo,[118] B. R. Drell,[118] W. T. Ford,[118] B. Heyburn,[118] E. Luiggi Lopez,[118] U. Nauenberg,[118] J. G. Smith,[118] K. Stenson,[118] K. A. Ulmer,[118] S. R. Wagner,[118] S. L. Zang,[118] L. Agostino,[119] J. Alexander,[119] F. Blekman,[119] A. Chatterjee,[119] S. Das,[119] N. Eggert,[119] L. J. Fields,[119] L. K. Gibbons,[119] B. Heltsley,[119] W. Hopkins,[119] A. Khukhunaishvili,[119] B. Kreis,[119] V. Kuznetsov,[119] G. Nicolas Kaufman,[119] J. R. Patterson,[119] D. Puigh,[119] D. Riley,[119] A. Ryd,[119] X. Shi,[119] W. Sun,[119] W. D. Teo,[119] J. Thom,[119] J. Thompson,[119] J. Vaughan,[119] Y. Weng,[119] P. Wittich,[119] A. Biselli,[120] G. Cirino,[120] D. Winn,[120] S. Abdullin,[121] M. Albrow,[121] J. Anderson,[121] G. Apollinari,[121] M. Atac,[121] J. A. Bakken,[121] S. Banerjee,[121] L. A. T. Bauerdick,[121] A. Beretvas,[121] J. Berryhill,[121] P. C. Bhat,[121] I. Bloch,[121] F. Borcherding,[121] K. Burkett,[121] J. N. Butler,[121] V. Chetluru,[121] H. W. K. Cheung,[121] F. Chlebana,[121] S. Cihangir,[121] M. Demarteau,[121] D. P. Eartly,[121] V. D. Elvira,[121] I. Fisk,[121] J. Freeman,[121] Y. Gao,[121] E. Gottschalk,[121] D. Green,[121] O. Gutsche,[121] A. Hahn,[121] J. Hanlon,[121] R. M. Harris,[121] E. James,[121] H. Jensen,[121] M. Johnson,[121] U. Joshi,[121] R. Khatiwada,[121] B. Kilminster,[121] B. Klima,[121] K. Kousouris,[121] S. Kunori,[121] S. Kwan,[121] P. Limon,[121] R. Lipton,[121] J. Lykken,[121] K. Maeshima,[121] J. M. Marraffino,[121] D. Mason,[121] P. McBride,[121] T. McCauley,[121] T. Miao,[121] K. Mishra,[121] S. Mrenna,[121] Y. Musienko,[121,s] C. Newman-Holmes,[121] V. O'Dell,[121] S. Popescu,[121] R. Pordes,[121] O. Prokofyev,[121] N. Saoulidou,[121] E. Sexton-Kennedy,[121] S. Sharma,[121] R. P. Smith,[121,a] A. Soha,[121] W. J. Spalding,[121] L. Spiegel,[121] P. Tan,[121] L. Taylor,[121] S. Tkaczyk,[121] L. Uplegger,[121] E. W. Vaandering,[121] R. Vidal,[121] J. Whitmore,[121] W. Wu,[121] F. Yumiceva,[121] J. C. Yun,[121] D. Acosta,[122] P. Avery,[122] D. Bourilkov,[122] M. Chen,[122] G. P. Di Giovanni,[122] D. Dobur,[122] A. Drozdetskiy,[122] R. D. Field,[122] Y. Fu,[122] I. K. Furic,[122] J. Gartner,[122] B. Kim,[122] S. Klimenko,[122] J. Konigsberg,[122] A. Korytov,[122] K. Kotov,[122] A. Kropivnitskaya,[122] T. Kypreos,[122] K. Matchev,[122] G. Mitselmakher,[122] Y. Pakhotin,[122] J. Piedra Gomez,[122] C. Prescott,[122] R. Remington,[122] M. Schmitt,[122] B. Scurlock,[122] P. Sellers,[122] D. Wang,[122] J. Yelton,[122] M. Zakaria,[122] C. Ceron,[123] V. Gaultney,[123] L. Kramer,[123] L. M. Lebolo,[123] S. Linn,[123] P. Markowitz,[123] G. Martinez,[123] D. Mesa,[123] J. L. Rodriguez,[123] T. Adams,[124] A. Askew,[124] J. Chen,[124] B. Diamond,[124] S. V. Gleyzer,[124] J. Haas,[124] S. Hagopian,[124] V. Hagopian,[124] M. Jenkins,[124] K. F. Johnson,[124] H. Prosper,[124] S. Sekmen,[124] V. Veeraraghavan,[124] M. M. Baarmand,[125] S. Guragain,[125] M. Hohlmann,[125] H. Kalakhety,[125] H. Mermerkaya,[125] R. Ralich,[125] I. Vodopiyanov,[125] M. R. Adams,[126] I. M. Anghel,[126] L. Apanasevich,[126] V. E. Bazterra,[126] R. R. Betts,[126] J. Callner,[126] R. Cavanaugh,[126] C. Dragoiu,[126] E. J. Garcia-Solis,[126] C. E. Gerber,[126] D. J. Hofman,[126] S. Khalatian,[126] F. Lacroix,[126] E. Shabalina,[126] A. Smoron,[126] D. Strom,[126] N. Varelas,[126] U. Akgun,[127] E. A. Albayrak,[127] B. Bilki,[127] K. Cankocak,[127] W. Clarida,[127] F. Duru,[127] C. K. Lae,[127] E. McCliment,[127] J.-P. Merlo,[127] A. Mestvirishvili,[127] A. Moeller,[127] J. Nachtman,[127] C. R. Newsom,[127] E. Norbeck,[127] J. Olson,[127] Y. Onel,[127] F. Ozok,[127] S. Sen,[127] J. Wetzel,[127] T. Yetkin,[127] K. Yi,[127] B. A. Barnett,[128] B. Blumenfeld,[128] A. Bonato,[128] C. Eskew,[128] D. Fehling,[128] G. Giurgiu,[128] A. V. Gritsan,[128] Z. J. Guo,[128] G. Hu,[128] P. Maksimovic,[128] S. Rappoccio,[128] M. Swartz,[128] N. V. Tran,[128] A. Whitbeck,[128] P. Baringer,[129] A. Bean,[129] G. Benelli,[129] O. Grachov,[129] M. Murray,[129] V. Radicci,[129] S. Sanders,[129] J. S. Wood,[129] V. Zhukova,[129] D. Bandurin,[130] T. Bolton,[130] I. Chakaberia,[130] A. Ivanov,[130] K. Kaadze,[130] Y. Maravin,[130] S. Shrestha,[130] I. Svintradze,[130] Z. Wan,[130] J. Gronberg,[131] D. Lange,[131] D. Wright,[131] D. Baden,[132] M. Boutemeur,[132] S. C. Eno,[132] D. Ferencek,[132] N. J. Hadley,[132] R. G. Kellogg,[132] M. Kirn,[132] A. Mignerey,[132] K. Rossato,[132] P. Rumerio,[132] F. Santanastasio,[132] A. Skuja,[132] J. Temple,[132] M. B. Tonjes,[132] S. C. Tonwar,[132] E. Twedt,[132] B. Alver,[133] G. Bauer,[133] J. Bendavid,[133] W. Busza,[133] E. Butz,[133] I. A. Cali,[133] M. Chan,[133] D. D'Enterria,[133] P. Everaerts,[133] G. Gomez Ceballos,[133] M. Goncharov,[133] K. A. Hahn,[133] P. Harris,[133] Y. Kim,[133] M. Klute,[133] Y.-J. Lee,[133] W. Li,[133] C. Loizides,[133] P. D. Luckey,[133] T. Ma,[133] S. Nahn,[133] C. Paus,[133] C. Roland,[133] G. Roland,[133] M. Rudolph,[133] G. S. F. Stephans,[133] K. Sumorok,[133] K. Sung,[133] E. A. Wenger,[133] B. Wyslouch,[133] S. Xie,[133] Y. Yilmaz,[133] A. S. Yoon,[133] M. Zanetti,[133] P. Cole,[134] S. I. Cooper,[134] P. Cushman,[134] B. Dahmes,[134] A. De Benedetti,[134] P. R. Dudero,[134] G. Franzoni,[134] J. Haupt,[134] K. Klapoetke,[134] Y. Kubota,[134] J. Mans,[134] D. Petyt,[134] V. Rekovic,[134] R. Rusack,[134] M. Sasseville,[134] A. Singovsky,[134] L. M. Cremaldi,[135] R. Godang,[135] R. Kroeger,[135] L. Perera,[135] R. Rahmat,[135] D. A. Sanders,[135] P. Sonnek,[135] D. Summers,[135] K. Bloom,[136] S. Bose,[136] J. Butt,[136] D. R. Claes,[136] A. Dominguez,[136] M. Eads,[136] J. Keller,[136] T. Kelly,[136] I. Kravchenko,[136] J. Lazo-Flores,[136] C. Lundstedt,[136] H. Malbouisson,[136] S. Malik,[136] G. R. Snow,[136] U. Baur,[137] I. Iashvili,[137] A. Kharchilava,[137] A. Kumar,[137] K. Smith,[137] M. Strang,[137] J. Zennamo,[137] G. Alverson,[138] E. Barberis,[138] D. Baumgartel,[138] O. Boeriu,[138] S. Reucroft,[138] J. Swain,[138] D. Wood,[138] J. Zhang,[138] A. Anastassov,[139] A. Kubik,[139] R. A. Ofierzynski,[139] A. Pozdnyakov,[139] M. Schmitt,[139] S. Stoynev,[139] M. Velasco,[139] S. Won,[139] L. Antonelli,[140] D. Berry,[140] M. Hildreth,[140] C. Jessop,[140] D. J. Karmgard,[140] J. Kolb,[140] T. Kolberg,[140]

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